

PATTERNING METHOD

The present invention relates to a method for patterning a device layer and to devices made using the method. The invention is particularly concerned with a method for patterning an optoelectronic device layer that is simpler and more cost effective than previously known methods.

One class of optoelectronic device that is of particular interest of the present invention is an organic light-emitting device (OLED). These devices employ an organic material for emission.

Polymers are an attractive choice for use in OLED devices. For example, WO 90/13148 describes such a device comprising a semiconductor layer comprising a polymer film that comprises at least one conjugated polymer situated between electrodes. Other polymer layers capable of transporting holes or transporting electrons to the emissive layer may be incorporated into such devices.

Figure 1 shows a cross section of a typical OLED device. Anode 1 typically is a layer of transparent indium-tin oxide (ITO). The ITO is covered with at least a layer of a thin film of an electroluminescent organic material 3. A hole transport layer 4 is provided between the ITO and the organic material. A final layer forming a cathode 4, which is typically a metal or metal alloy is provided.

In order to fabricate the device structure, various techniques for fabricating nano structures have been developed. To obtain

functional devices it often is necessary to pattern the active device layers and the electrodes.

Organic light emitting devices (OLED's) which make use of thin films of polymer are becoming an increasingly popular technology for applications in devices comprising a plurality of OLED pixels arranged to form a display, such as a flat panel display (FPD). Such an OLED including a pixel arrangement typically comprises a plurality of luminescent pixels that are arranged in a matrix form.

To form an array of OLED's, constituent materials must be patterned. A pixelated OLED device includes, for example, a plurality of first electrode strips formed on a substrate. The strips are arranged in a first direction. One or more organic layers are formed on the first electrode strips. A plurality of second electrode strips is formed over the organic layers in a second direction that typically is orthogonal to the first direction. The intersections of the first and second electrode strips form pixels.

Patterning active device layers and electrodes previously has been done using standard photolithography processing.

Standard photolithography processing typically involves photolithographic and etching techniques. Photolithographic techniques all share the following operational principal; -exposure of an appropriate material to electromagnetic radiation in order to introduce a latent image into the material as a result of a set of chemical changes in its molecular structure;

-subsequent developing of the latent image into relief structures through chemical etching.

Patterning of the latent image can be achieved by interposing a mask between the source of radiation and the material. When masks are used, the lithographic process yields on the material a replica of the pattern on the mask.

This method commonly has been used to produce a patterned anode on a substrate, for example ITO tracks on a glass substrate. For example, a photosensitive resist layer is deposited as a layer on an anode layer. The resist layer is exposed with radiation having the desired pattern defined by a mask. After development, unwanted resist is removed to expose portions of the anode beneath. The exposed portions are removed by a wet etch, leaving the desired pattern on the anode layer. Cathode strips may be created similarly. It can be seen that this conventional technique requires numerous steps, increasing raw process time and manufacturing costs.

Several problems have arisen in the chemical etching of some materials and the chemical compatibility of some materials with conventional photoresists. Particularly, standard photolithography processing is not suitable for some polymers because the surface could be exposed to solvents or UV light, which might cause material degradation. Thus, it has been considered that there is a need to develop special patterning techniques for polymers. It therefore has been considered desirable to pattern conducting electrodes and semiconducting polymers in devices with non-photolithographic techniques.

One alternative to photolithography is soft lithography. This is the collective name for a set of lithographic techniques using a

patterned elastomer stamp to generate or transfer the pattern. Soft lithography patterning techniques are based on physical contact, not the projection of light through a mask, as in photolithography. Soft lithography offers immediate advantages over photolithography for applications in which patterning non-planar substrates, unusual materials, or large area patterning are the major concerns. As described in Advanced Materials 2000, 12 No. 4 page 269 to 273, there are several advantages of using soft lithography compared to conventional photolithography: it is less costly, has no optical diffraction limit, allows control of the chemistry of a patterned surfaced, does not expose the sample to high-energy radiation and can easily be applied to non-planar surfaces. Soft lithography is a gentle process that therefore is of great interest for patterning sensitive materials such as polymers.

Soft lithography includes microcontact printing (μ CP); replica moulding, self assembled monolayers; put-down and lift-up; and micromoulding in capillaries (MIMIC) techniques.

A replica moulding technique is summarised in Figure 1 of Advanced Materials. 2000, 12 No. 3 page 189 to 195 [Is this correct?]. A patterned elastomer is put in conformal contact with an active polymeric film area and the assembly is brought to the polymer softness transition temperature. After cooling, the patterned elastomer stamp is removed and leaves the grating pattern on the polymer surface. This technique also is generally described in Figure 3(A) of Chemical Reviews 1999, Vol. 99 No. 7 page 1823 to 1848.

Three different general methods of soft lithography are summarised in Figure 1 on page 270 of Advanced Materials 200, 12

No. 4. This Figure is reproduced in Figure 2 of the present application. It can be seen that, in general, microcontact printing and lift-up both involve a transfer of polymer material either from the rubber stamp to the substrate or from the substrate to the rubber stamp. The MIMIC technique necessitates introducing polymer material into capillaries that are formed when the stamp is in conformal contact with the substrate.

The specific disclosure of this document is limited to microcontact printing of PEDOT-PSS onto ITO substrate; microcontact printing of PEDOT-PSS onto gold substrate; lift-up of PEDOT-PSS on glass substrate and micromoulding in capillaries of polyurethane. The MIMIC method was used to pattern the thermally evaporated aluminium cathode and the other two methods patterned the anode. Electrically separated anode lines were achieved by putting PEDOT-PSS onto gold and, through wet etching, removing the gold between the PEDOT-PSS lines.

WO 01/04938 provides an alternative to conventional photolithographic and etching techniques. The method uses a stamp made of a hard material such as steel, silicon, or ceramic. A pattern is defined by protrusions on the surface of the stamp. A load is applied on the stamp forcing the stamp against the substrate. This causes the pattern on the stamp to be transferred to the substrate [Is this some kind of replica moulding technique? Would a hard stamp be of any use in the present method?].

A specific lift-up [correct?] technique is described in WO 01/39288. This document relates to patterning an electrode layer using a silicon stamp. The patterned stamp is coated with an adhesive material such as a metal. The patterned stamp is

removed such that the portions of the electrode layer in contact with the raised portions of the stamp are removed with the stamp.

As acknowledged in WO 00/70406, the stamp material used in many soft lithography techniques is problematic when used in combination with polymers solvated in some organic solvents such as isopropanol, xylene, chloroform or water. Isopropanol, xylene and chloroform prevent the patterning of many polymers because these solvents can swell the stamp and destroy the fine pattern to be transferred. Alternatively, the patterning of water-soluble polymers prohibits the use of some soft lithography techniques such as MIMIC as water is not easily transported through the extremely non-polar elastomeric stamp.

In order to address this problem, WO 00/70406 provides a method for patterning a polymer film that involves depositing onto a material surface a thin film of polymer, applying to the material surface a stamp made of an elastomeric material in conformal contact with the surface of the thin film. Portions of the thin film contact one or more protruding elements of the elastomeric stamp and are attached to the protruding element. These portions are removed from the material surface with the stamp. In the method, no solvent is used. The method can be considered to be a "lift-up" soft lithography method [correct?]. An equivalent "put-down" method the "lift-up" method also is described in this document.

An alternative method is to combine soft lithography with the self-assembled monolayer technique. A hydrophilic monolayer pattern residing on a hydrophobic background, or a hydrophobic monolayer pattern residing on a hydrophilic background, will

direct polymer solutions on the surface to selectively wet and spread on one of these regions, and finally a duplicated polymer pattern forms after solvent evaporation. This method can be controlled by the liquid and solid surface free energy. However, the method requires suitable monolayer material being transferred to a patterned area, which is probably unwanted in the final structure. The chemical step involved in the transfer of the self-assembled monolayer also influences the final properties of the patterned film.

In parallel [correct?] with the above mentioned soft lithography techniques for fabricating patterned nano structures, in recent years, technology has been under development for obtaining functional devices by forming prescribed patterns by applying thin films having different properties onto different zones on the same substrate. However, a problem arises at the process surface in that the different thin film materials become mixed on the substrate. This is because the liquid material that is discharged into one zone on the substrate flows over into adjacent zones. What is commonly done to overcome problems such as this is to provide protruding portioning members (called "banks" or "rises") to partition off different thin film zones and then to fill the areas enclosed by these portioning members with the liquid materials constituting the different thin films. In the context of a pixelated OLED device, banks may be provided to partition off the various pixels.

The use of banks is described in EP 0880303. In EP 0880303, it is stated that in order to realize a full colour display device, it is necessary to arrange organic luminescent layers that emit any one of red, green and blue for the respective pixels. It is further stated that a problem with this is that it is difficult

to carry out patterning with high precision. As such, EP 0880303 provides banks to fill the spaces between the pixel electrodes to prevent mixing of colours of the luminescent materials.

EP 0989778 is also concerned with thin film formation technology that uses banks. The method aims to overcome problems with existing bank technology and involves subjecting the banks to a surface treatment under conditions such that the degree of non-affinity exhibited by the banks for the liquid thin film material is modified. Reduced pressure plasma treatments and atmospheric pressure plasma treatments are mentioned. Further, a combination of oxygen plasma treatment and fluorene-based gas plasma treatment is mentioned. The method does not use a stamp. [What is the mechanism of these plasma treatments? Are chemical groups on the treated surface rearranged or removed?].

It will be appreciated that the use of banks complicates the process of manufacturing a device and thus makes it less time and cost effective.

Therefore, it is an object of the present invention to provide a simplified but effective method for patterning a device layer.

In a second embodiment of the present method, in step (2) the surface energy of any portion of the substrate that is not in contact with the patterned elastomer is modified. In this embodiment, the patterned elastomer is used as a mask in step (2) and step (2) includes subjecting any portion of the surface of the substrate that is not in contact with the patterned elastomer to a surface energy modifying process. Any suitable surface energy modifying process known in the art may be used so long as it produces the desired effect. Suitable surface energy

modifying processes include exposure to UV radiation, plasma treatment [?] [Any other?].

The second embodiment of the present method will be particularly useful when the substrate material is not responsive to surface modification merely by bringing a patterned elastomer into contact with the substrate. A notable substrate material in this regard is indium tin oxide, a common material used for the anode in OLEDs.
